MURPHY

Methods of Concrete Construction

Civil Engineering

B. S.

1913

UNIV. OF
ILLINOIS
LIBRARY

THE UNIVERSITY
OF ILLINOIS
LIBRARY

1913
M95.

Digitized by the Internet Archive
in 2014

http://archive.org/details/methodsofconcret00murp

METHODS OF CONCRETE CONSTRUCTION

BY

KENDALL TUTTLE MURPHY

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1913

1913
M95

UNIVERSITY OF ILLINOIS

College of Engineering

May 24, 1913.

I recommend that the thesis prepared under my supervision by KENDALL TUTTLE MURPHY entitled Methods of Concrete Construction be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

Ira O. Baker.

Professor of Civil Engineering.

247422

UIUC

OUTLINE

METHODS OF CONCRETE CONSTRUCTION

1 Introduction
- (A) Purpose of subject
- (B) Limitations of subject
- (C) Assumptions

2 Supervision
- (A) Superintendant
- (B) General foreman
- (C) Assistant foreman

3 Organization of workmen
- (A) Systematizing positions
- (B) Weeding out poor hands
- (C) Classes of workmen

4 Construction prior to concreting
- (A) Preparing the pits
  - (1) The derrick
  - (2) The excavation
  - (3) The coffer dam
    - (a) The waling
    - (b) The sheet piling
    - (c) The pulsometer
  - (4) The bearing piles
    - (a) The driver
    - (b) Costs
- (B) Unloading material
  - (1) Sand
  - (2) Stone
  - (3) Cement
  - (4) Lumber
  - (5) Store houses

5 Intermediate construction
- (A) Pouring the foundation
  - (1) Method of mixing
  - (2) Organization of men
  - (3) Costs
- (B) Pouring the first step
  - (1) Forms
  - (2) Method of mixing
  - (3) Cars and tracks
- (C) Pouring the second step
  - (1) Forms
  - (2) Method of mixing
  - (3) Cars and tracks
- (D) Face-wall reinforcing
  - (1) Amount
  - (2) General type
  - (3) Temporary arrangement
  - (4) Final arrangement

6 Main construction
- (A) Building the main forms
  - (1) General plan
  - (2) Abutments
  - (3) Wing walls
  - (4) Cover
  - (5) Parapet walls

6 Main construction (Continued)
   (B) Car tracks
      (1) Bents
      (2) Supports on cover
      (3) Rails
      (4) Cars
      (5) Coal shutes
7 Pouring the concrete
   (A) Organization of men
      (1) Classes
      (2) Spaders
      (3) Car handlers
      (4) Wheelers
      (5) Cement carriers
      (6) Machine operators
   (B) Cost
   (C) Abutments
      (1) Method of pouring
      (2) Spading
      (3) Stopping off
   (D) Wing walls
      (1) Coal shutes
      (2) Slope walls
8 Bending the rods
   (A) Main rods
      (1) Method
      (2) Number of men
      (3) Cost
   (B) Stirrups
9 Placing the reinforcement
   (A) The main rods
   (B) The stirrups
   (C) System of sorting bars
   (D) The supports
10 Pouring the cover
   (A) Organization
   (B) Amount
      (1) Flushing
      (2) Spading
      (3) Settlement
      (4) Surface
      (5) Parapet walls
11 Tearing down the walls
   (A) The main walls
   (B) The cover
   (C) The sheet piling
12 The water proofing
   (A) Cleaning the surface
   (B) The primer
   (C) The asphalt
   (D) The gravel
13 Conclusions

METHODS OF CONCRETE CONSTRUCTION.

INTRODUCTION.

The purpose of this thesis is to describe in a general way some practical methods and new devices for mixing and placing concrete which have been observed by the writer during several year's work on different jobs in the capacities of laborer, "straw boss", carpenter foreman, inspector, and general foreman. It is not the intention to discuss any of those tricks or methods which contractors often employ to add dishonestly to their own reputation or profits; but an attempt will be made to confine the discussion to matters that are generally accepted by the more competent engineers and contractors. Although the methods set forth have been obtained from experience in many lines of work, they will be described as applied to new and moderately massive railroad construction, particularly to a twenty-foot culvert having a 3 1/2-foot reinforced-concrete slab-cover and a wood-pile foundation. The discussion will be confined to the actual construction; and the writer will assume that the other departments of the work are carried on with the same degree of efficiency that is expected of the department doing the actual construction. It will also be assumed that the construction is being carried on by a company that is of first-class standing and capable of a moderate amount of construction each year.

The above mentioned piece of work has been chosen from among others of a similar nature with which the writer is familiar, because it afforded a better opportunity for applying labor and

money-saving devices than the others that were under construction at the same time, on account of its being almost completely isolated from other jobs being put up by the same firm under the same contract, and also because it was not necessary to rush it like most of the other jobs. Furthermore, labor could be taken off and on at will, as there were other jobs near by on which the labor could be used without loss. In this way the culvert chosen is in some respects a little more ideal than under ordinary conditions; but the results obtained on this work may, if care is taken, be duplicated on most similar ones.

After a brief discussion relating to the qualifications of a good foreman and the organization of his assistants and workmen, the actual steps in the construction of the culvert will be taken up in their natural order.

THE GENERAL FOREMAN.

As the general foreman is usually the highest executive in the company's employ who is constantly on the job, it is desirable to know something about the qualifications necessary for such a position.

In the first place, to turn out work for his firm in an advantageous manner, a foreman must have a clearly defined agreement with his firm. He must have supreme and direct executive power in the vicinity of the work in his charge. He should have authority to buy any materials or supplies he thinks necessary, which are not furnished from the firm's headquarters. He should have power of hiring and discharging as he thinks best; and should

have authority of setting wages as he sees fit, especially where he is not dictated to by unions, etc. He should have direct charge of the pay roll and account sheets so as to be familiar with the costs. The general foreman should have under him competent assistants of his own choosing so that it is not necessary for him to attend to minor details when he should be using his time in overseeing more important features of the work. And above all, it is important that his employers shall have the utmost confidence in him, and be in close touch with his work constantly so that he will know and realize that his efforts are noticed and appreciated. For his own part, a foreman should have the interests of his firm in view at all times, and as he will often have to sacrifice his own interests for those of the firm, it is necessary that he have a mind capable of making sacrifices without flinching. He should feel that his firm is the best of its kind, and that his best efforts will be appreciated. He should not employ methods by which he would profit, if there is any chance of his firm's being the loser; and he should employ all methods possible to increase the earnings of the company without slighting the job or doing injustice to those connected with it. Above all he should consider the work his work, and make it his one desire to see that is a complete success.

ASSISTANT FOREMAN.

The general foreman should have at least one assistant foreman for every piece of work in his charge, either a man doing regular supervising work, or one of the workmen who is known to the rest of the men as having the authority of an assistant foreman.

If a number of carpenters are being employed, the head carpenter may act as assistant foreman; or if the work has not advanced to that stage, the head mechanic of the pile driver may act as assistant to the foreman. Or an assistant foreman may be employed who is directly responsible to the general foreman. A foreman should as a rule choose his assistants from the men, as this encourages competition among them for such positions, thus raising their efficiency. It is better to pick a man as assistant from observation rather than to take one who comes recommended, since often such men will not live up to the foreman's idea of an assistant. The general foreman should at all times take his assistants into his confidence, so that they can work together in their plans for the work. An assistant is always more likely to be on the lookout for labor-saving methods, if he thinks that his foreman will be willing to allow his plans to be used. As the work progresses, such cooperation always shows itself advantageously. The same relations then should exist between the general foreman and his assistants that exist between the company and the foreman.

ORGANIZATION OF THE WORKMEN.

As the foreman has the power of hiring all the men, he has a good opportunity, under most conditions, to organize as efficient a gang of men as could be desired. By observing the interest that the various men take in the work, as well as their abilities, he is able to place the best men in the places where their efficiency is most effective. For example, under most carefully organized systems, the capacity of a machine-mixing outfit

depends upon the rapidity with which the machine turns out batches, and that rapidity in turn depends upon the skillful manipulation of the machine by the operator; hence by putting the right man in charge of the mixer, one who is willing and competent, the capacity of the mixer may be increased twenty-five per cent, since without a competent man in that place, the whole crew is held up by the slowness of operation, and in a day's run, even though the part the operator plays is comparatively small there may be considerable loss. The swiftness and intelligence of one man operating the machine has a great deal to do with increasing the amount of work turned out by a gang of men. It pays to place in the more responsible positions, the men who show fitness and willingness, even perhaps to pay them more for their efforts.

On the job considered in this discussion the laborers were comparatively green foreigners of more than one nationality; but their work was surprisingly gratifying, owing to the fact that each one of them was given individual supervision and recognition either by the foreman or one of his assistants. They were made to understand that they were not to be treated like so many ungovernable beings who could not understand; and consequently there was a perceptible rivalry among them to do the work as they were shown. An interpreter was unnecessary, even though the gang was nearly as ignorant as a gang could be. Since foreign laborers usually come in gangs, it is not always possible at first to have every man in the gang a good one; but by good judgment and careful management the undesirable ones may be got rid of, and better ones added. In the course of several weeks the gang ought to be

composed of desirable laborers.

The remaining men were picked from those available among all classes of American workmen. Of course, it is natural that often men will be hired who are incompetent, but by carefully directed observations the best may be retained. The carpenter foreman should be a steady, heady man who is capable and has the good will of the men in his charge. The stationary engineer should be an expert in his line, quick and eager to see that the work is kept moving.

THE DERRICK.

The most notable piece of machinery used in the construction of the culvert was undoubtedly the derrick. That it was notable was not due to the fact that it was an up-to-date derrick, manufactured by those who make a specialty of such work and embodying all the latest desired features; but it was due to the fact that it was constructed on the site of the culvert, out of available material, by unskilled workmen, and without excessive expense. The setting up of a stiff-leg derrick was unjustifiable for two reasons. One was that the amount of excavation was so small that, even if the actual cost of excavating the earth were reduced, the additional expense of hauling and setting up the better derrick would have more than offset the reduction in the cost of the excavation. In addition, the right-of-way was not wide enough to allow the passage of teams, the hauling of material, and the throwing up of embankment. Consequently it was decided to construct a derrick on the spot and use for power the hoist that would have to be used later on for hoisting the concrete. As this particular

PLATE 1.

One of the derricks in full operation. The boom which was made of two timbers is delivering a load of earth to the dump along the creek channel. The mast with two guy wires are shown, as well as part of the circular table and braces. The bucket in the fore ground is the same type as shown in Plate 2. In the rear is shown the hoist and also another derrick of about the same general type. The sheet piling are driven to about one half the final depth.

hoist had only two drums, it was necessary to procure a small turbine and drum to produce the third motion. The turbine and drum were even better adapted to swinging the boom than an ordinary drum as it was easier controlled, and thus gave a smoother and safer motion. The mast was made from a single piece of 12- by 12-inch timber, 20 feet long. The only important framing necessary on the mast was that for a forged iron box at the top. This box held a ring to which a double block could be hooked, and it also had a pin on it over which a ring holding the guy-wires could be placed. A little framing was necessary at the bottom for the iron box that rested on a shoe on the foundation, to afford means of the derrick's rotation. As the ground was comparatively soft and rains were frequent, the foundation for the mast was made by securely drifting together six pieces of 6-by 8-inch timbers, 6 feet long, laid flat-wise. This foundation was staked securely, expecially in the direction of the hoist, which was placed about forty feet back of the derrick. Besides furnishing a bearing for the derrick, this foundation afforded a place to which a double block could be hooked to carry the lead lines from the hoist drums up to the block at the top of the mast and thence to the end of the boom and down to the bucket. A little difficulty was encountered in rigidly fastening a framed swinging-platform to the bottom portion of the mast; but finally when it was decided to build a solid, six-foot circular table directly to the mast, the difficulty was overcome. The 5/8-inch cable for swinging the derrick was passed around the wooden table one complete turn and back to the turbine drum. As the cable was always kept taut in both directions by a turn-buckle

placed half-way between the cable and the hoist, the cable was bolted neither to the table nor to the small drum that was turned by the turbine. The boom was made from two pieces of 8-by 8-inch timber, 20 feet long, spliced together with a 4-foot lap slightly dapped down and bound together by four square forged iron bands. The lower end of the boom was carefully rounded and set in a framed oak block bolted to the bottom of the mast, and was kept well soaped. At the upper end of the boom was fitted an iron band to which a single boom line was attached. The line ran through the block at the top of the mast, thence through the block at the drifted foundation and back to the hoist. It was necessary to frame a single sheave into the end of the boom to carry the load line that ran through the same blocks as the boom line. The load line lifted the buckets by a single block directly above the bucket. The four guy-wires were made of 3/4-inch twisted steel cable about 120 feet long, fastened at one end to the top of the mast by the ring over the pin and the other end to dead men placed the required distance from the derrick. A pulling jack was used to tighten the guy-wires before they were bolted.

Half-yard self-dumping buckets were used in the excavation of the pits. The derrick was used for driving the sheet piling and waling as well as for elevating the earth. The derrick, set up as it was, elevated all the earth and did all the driving with little or no difficulty. When the derrick was torn down, the hoist was used to elevate the concrete, the guy-wires were practically as good as new; and the mast, boom, etc., could be used over for any purposes desired. It was estimated, after the derrick had completed the excavation, that the total cost of making and setting

up the derrick was about one fourth of the amount that would have been necessary to haul and set up a stiff-leg derrick.

THE EXCAVATION.

While the derrick was being built and set up, the gang of laborers throwing the earth out by hand, commenced to excavate the pits to a depth of about four feet on the lines staked out by the engineers. As the ground was free from excessive moisture and at that depth showed little tendency to cave in, the pits were dug to exact size with vertical walls just a little larger than the overall dimensions of the specified coffer dam. While this excavation was going on, the carpenters were building three sets of waling, as it was estimated at that time that the pits would have to go down at least 13 or 14 feet below the surface of the ground. This depth was necessary because at a later date the bed of the creek was to be diverted so as to go through the culvert; and consequently piles would have to be used. These sets of waling were carefully made so that they might be easily removed as fast as the concrete rose in the dam, without interfering with the concreting; and therefore, all pieces that were to come to a tight fit, due to the pressure of the earth, were given a slight bevel so as to allow them to be knocked apart easily when once they were started. All splices and connections were made of two-inch scabs, nailed just enough to hold the parts together until the pressure of the earth became enough to hold them securely. The members of each set were put in in the order that was to be followed when they were removed.

By the time the pits were ready for the coffer dam, the timbers and sheet piling were ready, and so the laborers were put

PLATE 2.

One of the pits about one half finished, showing the sheet piling, waling, and cross frames. The pulsometer which was ordinarily used to remove the small amount of water from the pits, was at this time re-placed by a small gasoline-driven centrifugal pump. The lower portion of the derrick is shown to the right, including the circular table, its bracing, and the boom with its brace lines. The bucket shown in the lower left hand corner is of the type ordinarily used with such outfits. The posts separating the two sets of waling, as well as the scabs connecting the various members of the waling, are clearly shown.

to unloading materials while the carpenters placed the coffer dam. The lower set of timbers was placed at the bottom of the pits and scabbed together completely. Then 4-foot posts were placed at the joints of the waling timbers, and the second or middle set of waling timbers placed on top of the posts. After the two sets of timbers were placed, they were cross-braced sufficiently to keep the coffer dam in a true course as it was driven down. The sheet piling was then placed between the waling and the sides of the pits, and nailed lightly to the waling to hold it until it was driven. The regular length of piling was fourteen feet, but shorter lengths were placed on the side nearest the derrick where two lengths were used in place of one to allow the boom to come down close to the ground. The sheet piling was not sharpened, as the earth was dug out below the piling before it was again driven. Holes were bored in the top of the piles to afford a place to fasten hooks so that they could be pulled after the concrete had set and the abutment steps had been built. As water was not present in sufficient quantities to make it necessary to keep it out entirely, ordinary three-inch plank was used for sheet piling.

The derrick, operated by an engineer and fireman, delivered empty buckets to the workmen at any place in the pits and removed the full ones as fast as eighteen laborers could fill them. A man was used to trip the buckets on the dump and to keep the dump leveled off. The assistant foreman directed the work and at the same time gave signals to the engineer for lowering, raising, and swinging the buckets. By working the bucket and boom lines together a bucket could be placed in any part of the pits and removed without endangering the bracing of the coffer dam.

The arrangement of the double blocks prevented the making of a complete revolution of the boom, but there was opportunity to swing the boom about three-quarters of a revolution, and that was sufficient to reach any part of the pits and also to dump the earth clear of the work. As a fill was later to be made over the culvert, the waste earth was allowed to remain where it fell. At first the sheet piling was driven by a man with a heavy maul; but after the friction of the earth prevented this, the derrick lowered a block on concrete, molded to the right dimensions,on thetops of the sheet piling, which drove them down easily. When the bottoms of all the sheet piles reached about 2 1/2 feet below the lower waling, the concrete block was lowered on the upper waling which sank and in turn drove the lower set of waling. The flexible scab connections allowed the coffer dam to sink in this manner. As soon as practicable the last or upper set of waling was put in place, and separated from the middle set by 5-foot posts.

The coffer dam was now complete, permitting a depth of at least fifteen feet. At a depth of about seven feet the amount of water encountered hindered the workmen. So the excavation was continued from this depth on, in such a manner as to allow the pits to drain themselves into sumps at their ends. The water was removed by a pulsometer which could be lowered to any depth desired by means of a block and tackle attached to a timber laid across the upper set of waling. The steam was furnished by the boiler of the hoist engine, as the derrick did not use enough steam to overtax the boiler. The pits were finally decided to be deep enough at twelve feet. At this point a good clay was found that had considerable coarse sand mixed with it. The lower set of waling was now

about 2 feet above the bottom of the pits, a sufficient depth to pour a layer of concrete without covering the lower waling. The pits were then ready for the bearing piles, which were driven immediately.

DRIVING THE PILES.

On account of the great depth of the abutments and also the porosity of the sub-soil, it was decided that 18-foot bearing piles would have to be driven, although the driving would have to be carried on under some difficulties. The main difficulty was that a large part of the driving would have to be done in the pits between the cross waling where an ordinary driver could not go unless an excessive length of pile heads was cut off above the bottom of the pit. For this reason lighter piles were driven than would have been ordinarily, and a light steam-hammer pile-driver was used to do the driving. The driver was mounted on two 12-by 12-inch mounting timbers that extended the whole length of boiler, hoist, frame and tower. Four blocks were made having one face covered in the form of a segment of a 12-inch circle. These works were bolted to the two mounting timbers with the semicircular face down. The curved faces of these blocks rested on two 20-foot 12-inch hollow steel rollers that revolved as the driver moved forward or backward, and were kept well soaped to facilitate sliding. Bridge stringers were placed flat-wise along the sides of the pits and blocked up to a level so as to make a good track for the rollers. The backward and forward motion of the driver was made by turning a line around first one roller and then the other, and running it through

a block staked in front or back of the driver, and then to a nigger-head on the hoist. The side movement of the driver was made by drawing in a line that ran from the mounting timbers through blocks at one end of each roller. Little or no difficulty was found in spotting the driver over a pile after the oak blocks and rollers had become well soaped.

Mounted as the driver was on top of the pits, the lowest position of the hammer was about nine feet above the cut-off elevation. To prevent wasting this length on every pile, the leaders were "boot-legged" down to the required length. This extension was made easily detachable so as to facilitate the moving of the driver from one section of the pit to another. As there were about twelve piles to every section, the time lost in unfastening the extension was small. The pile-driver crew consisted of five men, an engineer, a fireman, a "spotter", a "hooker", and a "leadman". The duties of the engineer and fireman were those ordinarily performed by such men. The engineer controlled the clutches that lowered and raised the hammer and the pile line, as well as controlled the steam in the hammer itself. The fireman kept up steam and assisted in other places at times when his firing duties were not pressing. The "spotter" located the pile as it was being lowered in the leads, gave signals for moving the driver, and kept track of the penetration. The "hooker" chained the piles to the load line, and with the assistance of one laborer pointed and capped the piles as fast as they were needed. The "leadman" placed the leather washer on top of the pile, unhooked the piles from the load line, and worked the lines on the nigger head.

This gang of men, working nine hours a day, drove the required number of piles, 288, in four and one half days, a very good record.

UNLOADING MATERIAL.

While the piles were being driven, the laborers were unloading stone, sand, and cement from cars that had been side-tracked as near as possible to the site of the culvert, about three-quarters of a mile away. Since the greater part of the stone and sand came in coal cars, it was necessary for the laborers to throw the material out by hand. The unavoidable expense of this operation was lessened considerably by attaching patent hoppers to the sides of the cars into which the workmen threw the material, even when there were no wagons at hand to receive it. These hoppers, built of sheet steel and resembling somewhat the small cups on belt elevators, were fastened to the sides of the cars by two strong, bent lugs each, that hooked over the sides; and could easily be moved by three men from one part of the car to another. Since they held about a cubic yard each, an average wagon load, they allowed the close checking up of the contents of a car. The hoppers were filled while the wagons were coming to and returning from the culvert, three being used to a car, one extra to allow the laborers opportunity to work in case the wagons were delayed at the dump. Eight men were placed in each car, four to a hopper when one of the hoppers was full. When sand was unloaded, however, the force in a car was cut down to six men.

The sand and stone were dumped in two piles each, one on each side of the place where the mixer was to be placed. This

arrangement allowed the teams to dump on one pile without interfering with the wheelers while they filled their barrows from the other pile; and also allowed the wheelers to go from one pile up one incline to the mixer and down the other to the second pile without delay on the mixer platform. Before any material was dumped, two-inch planks radiating from the mixer, were placed on the ground on the sites of all the piles, to give a good shoveling floor.

The small-sized Bain dump wagons were used because the haul was over bad roads and also because it was desired to pile the material up rather high on the dumps so that the men could load it easier into barrows. The drivers would drive directly under the hoppers, trip them, and thus load the wagon instantly. Eight wagons were necessary to keep sixteen shovelers busy. As the material at first was hauled faster than it was used, a snatch team was necessary to assist in pulling the wagons to the top of the dumps.

The cement came in box cars in lots of about eight hundred sacks, was immediately unloaded into Bain wagons, - the only available ones, - each of which held about thirty sacks, and stored in two, small, temporary sheds near the mixer. These sheds which were covered with tar paper, were built in sections so that they could be taken down and used over again; but they were made strong enough to prevent the sacks from pushing out the walls. As the surrounding land was flat and liable to overflow from nearby creeks, the floors were elevated about eighteen inches by being built on old pieces of timber.

Plenty of lumber was hauled from jobs farther up the line, and it was hauled to other jobs farther down the line when it was no longer needed on the culvert. All second-hand lumber

PLATE 3.

The carpentering gang eating dinner in the shade of one of the cement houses. The cement houses were built sufficiently well to keep out rain and also to withstand the pressure of the cement inside. The advantage of having two houses was in the fact that the mixer gang could use out of one house while the material gang could be unloading cement into the other house. They also served as store houses for other material when they were not in use as cement houses.

was looked over, sorted, and cleaned before the forms were started, so as not to hold up the carpenters when the form work was once begun.

POURING THE FOUNDATIONS.

Because of a desire to finish the culvert about the same time as some other jobs that had been started earlier, so as to transfer all of the men at the same time to the big river job some distance away, from this time on the work was rushed a little more than would otherwise have been necessary. The pits were ready for the concrete foundations and the necessary material was on hand; but the mixer would not be set up for a few days. To avoid delay it was decided to mix the concrete for the foundations by hand. It was estimated that with two mixing boards and two gangs of men the foundation in one pit could be completed in about three days.

The gang of men was organized into two bunches, each bunch using one cement shed, one sand pile, and one stone pile. This organization served to create a little rivalry between the two gangs, which materially increased the amount of work done each day. The mix was to have been a 1:3:6; but the sand was so coarse that a 1:4:5 mix was run most of the time. Each gang had sixteen men, making thirty-three in all counting the assistant foreman. The men in each gang were divided as follows: four wheeling sand, five wheeling stone, four mixing, one putting cement and water into batches, one wheeling cement, and one working in the pit. The water used for the concrete was part of that pumped out of the pits by the pulsometer.

The successive operations in mixing a batch were as

follows. The five stone wheelers loaded their barrows at the stone pile, wheeled them to the mixing board, and dumped them on the pile. The four mixers spread the stone out into a flat rectangular layer about three or four inches thick, eight feet long, and four feet wide. They made a little ridge on the edge of the layer to form a basin for the sand. About two buckets of water was then slopped over the stone by the extra man, to wet the surface of the stone before the cement was placed, and also to wet the surface of the board to facilitate the shoveling of the concrete into the pit after it was mixed. The four sand wheelers dumped the sand on the layer of stone, and the mixers spread it out. Two sacks of cement were then emptied on the stone and sand by the extra man, and spread out evenly over the layer. Then two of the mixers, one on each side of the layer, began to turn the batch through dry, by scooping their shovels under the layer at the same time, meeting in the middle of the layer; then by turning their shovels with their wrists and drawing back at the same time they completely turned over and mixed the layer without piling it up. They continued to turn until there was enough room behind them for the other two mixers to commence the same operation. The two pairs of shovelers went through the entire layer in this manner. When they were through, the layer was about the same size, shape, and depth as originally; but it had been moved about a foot on the mixing board. This process gave the concrete two good dry turnings. Then the extra man threw three or four pails of water on the concrete; and the first pair of mixers began to turn through the layer in the same manner that they did the first time. The extra man continued to throw on water where it was needed.

Then the other pair of mixers commenced to shovel the concrete off the edge of the board into the pit; giving it since it had to drop about twelve feet, what amounted to another wet turning. In this way the board was almost clear by the time that the first two mixers had finished the wet turning and was ready for the wheelers to bring in another batch. As a result batches were turned out about every five or six minutes, nearly as fast as an ordinary mixer can do it, without at the same time some of the objectionable features of the mixer. With the gang once running smoothly, no changes were made, and care was taken to keep all of the men working together so as not to delay the whole gang on account of one man. This organization gave every man a little chance to rest when necessary without delaying the entire gang.

The mixing board was made of one-inch sheeting nailed to four 4-by 6-inch studding which extended across the pit, so as to place the board directly above the foundation and thus make it necessary to shovel the concrete only a short distance after it had been mixed. The wheelers came on the board from one side, dumped their barrows, and went off the other side, and thence back to the piles.

The men in the pits kept the concrete well tamped around the pile heads, and saw to it that the concrete crowded the water to one end of the pit instead of allowing it to stand in puddles on the surface of the concrete. The pit men also kept in good condition the tar paper that had been tacked to the sheeting to facilitate pulling it. When the first layer of concrete had risen to the lower face of the waling timbers and had been allowed to

set a little, the men in the pits with some assistance knocked apart and removed the lower set of waling to afford opportunity for the concrete to rise to the proper elevation.

The pulsometer was so placed that it could deliver part of the water pumped, into barrels placed near the mixing boards. The cement wheelers delivered full sacks to the boards and removed the empty ones and tied them in bundles preparatory to shipping. The concrete in one pit amounted to about two hundred yards, and was placed in two days. The labor cost was about ninety cents a yard, which is low for board mixing.

When the first pit was completed to the required depth, the boards were transferred to the other pit; and the engineers laid off the lines for the first step of the foundation by driving nails into the soft concrete. As the forms for this step were to be placed below ground and the walls were vertical, great care was not necessary in building them. So the walls were built outside of the pits in sections and lowered into the pits, where very little carpenter work was necessary, as the forms were very simple. It was not necessary to wire these forms, as the sheeting afforded a good place against which short braces could be placed to hold the walls in their proper position.

By the time that this step was finished and the foundation of the second pit was completed, the mixer had been set up by the extra gang and was ready to take up the mixing. The mixer had been so placed that it would not have to be changed when the concrete was to be elevated for the upper part of the culvert. A temporary track, consequently, had to be laid to carry the concrete cars from the mixer to the pits in order to finish the concrete

PLATE 4.

The mixer gang sitting on the platform in front of the mixer. The inclines running up to the hopper from two opposite sides are shown, also the large platform in front of the hopper. The material piles were on opposite sides of the mixer which allowed the wheelers to pass up on one incline and down to the other pile without delay on the platform. A small part of the incline running up to the top of the forms is shown to the right, also the hoist used to elevate the concrete cars to the top of the forms. The tank just back of the mixer is an ordinary watering tank mounted on temporary bents, into which the pulsometer delivered water for the mixer and both boilers.

work up to the neat line. Between the pits a double track was laid with a switch to allow the use of two cars. These cars were of the side-hopper type, and proved very efficient. With this arrangement the foundation steps in both pits were finished. The second step was like the first, except that a little more care was used in the construction of the forms. It brought the concrete up to the neat line elevation, which was on about the same level as the surrounding ground. The mixing was then discontinued until the forms were ready for the upper parts of the culvert.

FACE-WALL REINFORCEMENT.

The plans called for about 1880 linear feet of face-wall reinforcing rods, part of which had to extend through the neat work of the abutment and into the cover as well as into the last step of the foundation. This reinforcement consisted of 16-foot 3/4-inch square-twisted steel bars placed vertically three inches back from the face of the abutment and one foot apart; and also thirteen rows of the same kind of bars twenty feet long placed horizontally one foot apart. It was necessary to place the vertical rods while the concrete of the last foundation step was still soft. This was done by pushing the rods into the concrete to a depth of about eighteen inches and tying them at the tops in bunches of threes to keep them in place until the concrete had set. This operation was simple, if done just at the time when the concrete was soft enough to permit the insertion of the rods and at the same time hard enough to keep the rods from sinking too far. As no more concrete was to be placed until the upper forms were completed, and as the reinforcement in its final position would hinder the carpenters in building the

forms, the vertical rods were bent down out of the way. The rods at the end of the row were bent down and towards the center, care being taken not to make the bend so short as to damage the material, and the free ends tied temporarily to the bottoms of the others. The rods in the center were then bent down and tied so as not to allow their ragged ends to project in a dangerous manner. In this position these rods took up only little room, and still could be bent back to their final positions without much trouble or serious damage. Later the vertical rods were bent back to place and the horizontal ones were wired to them at the intersections. The wires were cut in ten-inch lengths and bent at the center into long narrow "U's". The "U" was hooked around the vertical rod from the side opposite the horizontal bar, and then each end was bent down and around the horizontal bar and back around the vertical bar, where it was twisted with pliers by a single turn. Practically two wirings were thus given at each point, which was necessary as much climbing up and down on the reinforcement was to be expected. The lap of the horizontal bars was eighteen inches, but the vertical ones were long enough to be continuous from top to bottom. When finished and ready for the concreting, this reinforcement formed a large steel screen three inches from the face of the finished abutment. The placing and wiring of the horizontal bars was entirely completed before the concreting was resumed so as not to interrupt the pouring of the abutment.

BUILDING THE MAIN FORMS.

Everything was in readiness for the carpenters to build the remaining part of the forms. The laborers and concreting gang

PLATE 5.

View of the main forms just before they were ready for concrete. The incline, composed of ninety pound rail and simple bents, is shown as well as the main forms. The overturned shell from one of the cars is shown to the left. These shells were mounted on rocker supports which allowed them to be easily dumped.

were transferred to another job, and the carpenters were given complete control of the works. The plan proposed was to build the forms for the main abutments, wing-walls, steps, cover, and parapet walls at once. This was done for four reasons. First, it would then not be necessary to interrupt the concreters when once they resumed work. Second, the carpenters would not have to complete the forms under unfavorable conditions. Third, the forms could be constructed perfectly and all bracing could be made permanent and secure. And fourth, all the carpenters could be transferred to another job at one time when the forms were complete.

The first part of the forms constructed was the face walls of the abutments. The verticals were made of 4- by 6-inch hard pine posts, cut to the exact height so as to clear the under face of the cover, and placed every fourteen inches. These posts were stood on sills made of one-inch lumber nailed to the concrete foundation in such a position as to allow the sheeting to be placed on correct line when the posts came flush with the edge of the sill. The sills were shimmed up with wedges so as to make a level surface for the verticals. A one-inch cap was placed on top of the posts, on which the joists for the floor could be laid. The walls were then plumbed, and sway-braced from the inside just enough to hold them in position temporarily. As the cover was about five feet thick and had to be poured in one day's run, it was necessary to construct very strong supports to hold up the floor joists. This was done by erecting four sets of vertical bents between the abutments. The caps of these bents were made of 10- by 12-inch timbers and the posts were 8- by 10-inch timbers spaced every three feet in the direction of the axis of the culvert.

PLATE 6.

General view of the works showing the mixer, completed forms, and one cement house. The cars on top of the forms are of the side dump type but as they had to be pulled up the incline the back supports for the shell were elevated so as to not allow the concrete to spill out when going up the incline.

The foundations of these bents were made by setting two 8- by 10-inch bridge stringers in the ground with a block placed crosswise to distribute the pressure. Experience with similar jobs had shown that the bents would settle about two inches in that particular kind of soil. Because of this fact the floor of the cover was bowed upward about that amount to allow for the settling which could not entirely be avoided. Carefully made wedges were placed under each post so that they could be driven in and thus raise any part of the floor that might settle unduly.

The walls and the floor were then sheeted up. The temporary sway braces were knocked out, and strong permanent ones put in their place. This part of the forms gave a correct and secure structure on which to brace the remaining part of the forms. The face-walls for the wings were then constructed by putting the two end posts at the proper batter and placing the intermediate posts to a string line stretched between the tops of the end posts at the proper elevation. The posts were braced permanently by nailing struts to stakes driven in the ground. The back walls of the wings and of the abutments were built somewhat in the same manner as the face-walls. They were braced by placing spreaders of the proper length between the walls at the corresponding elevations. These spreaders were placed in tiers about five feet apart and about eight feet apart in the tier. Horizontal whales were placed on the outside of the wall posts at the spreader tiers. Wires were run around the whales and through the forms at each spreader. The spreaders kept the walls from being drawn too close together by the wires, and the twisted wires kept the walls from spreading. The spreaders were so placed that they could be knocked out by

PLATE 7.

The completed forms during concreting. Two of the men on top are car handlers, and the third is the assistant foreman. The sand wheelers to the right compose about one fourth of the wheelers, the rest being on the other side of the mixer.

the spaders as the concrete rose in the forms. The end walls were then put in place and wired down to prevent floating.

The end walls for the cover were then built and braced by struts nailed to the floor, which purposely had been built longer than necessary so as to afford footing for the struts. The inside walls for the parapet walls were then constructed on the ground, and hoisted into position and braced by spreaders and wires similar to the abutment walls. With the nailing of the molding around the entire form to give the proper elevation to which the concrete should be poured, the forms were completed.

Since the concrete would have to be elevated and poured into the forms from above, an inclined track was constructed from the mixer to the top of the forms. The bents for the inclined track were of the ordinary form, built of timber to the correct elevation. The supports on top of the culvert for the track were simple posts stood on the floor of the cover and boxed in by thin sheeting. They were so arranged that they could be knocked apart easily and removed, the hole being filled in afterwards with concrete. Ninety-pound rails were used for the track, which was supported by bents placed ten feet apart with no stringers or cross-ties. A wire cable ran from the hoist through a block at the top of the incline and back to the concrete cars. The cars after being hoisted were pushed to place by hand, dumped, and switched to let the next following car pass. Ordinary coal shutes were used to run the concrete into the wing walls.

POURING THE ABUTMENTS AND WING WALLS.

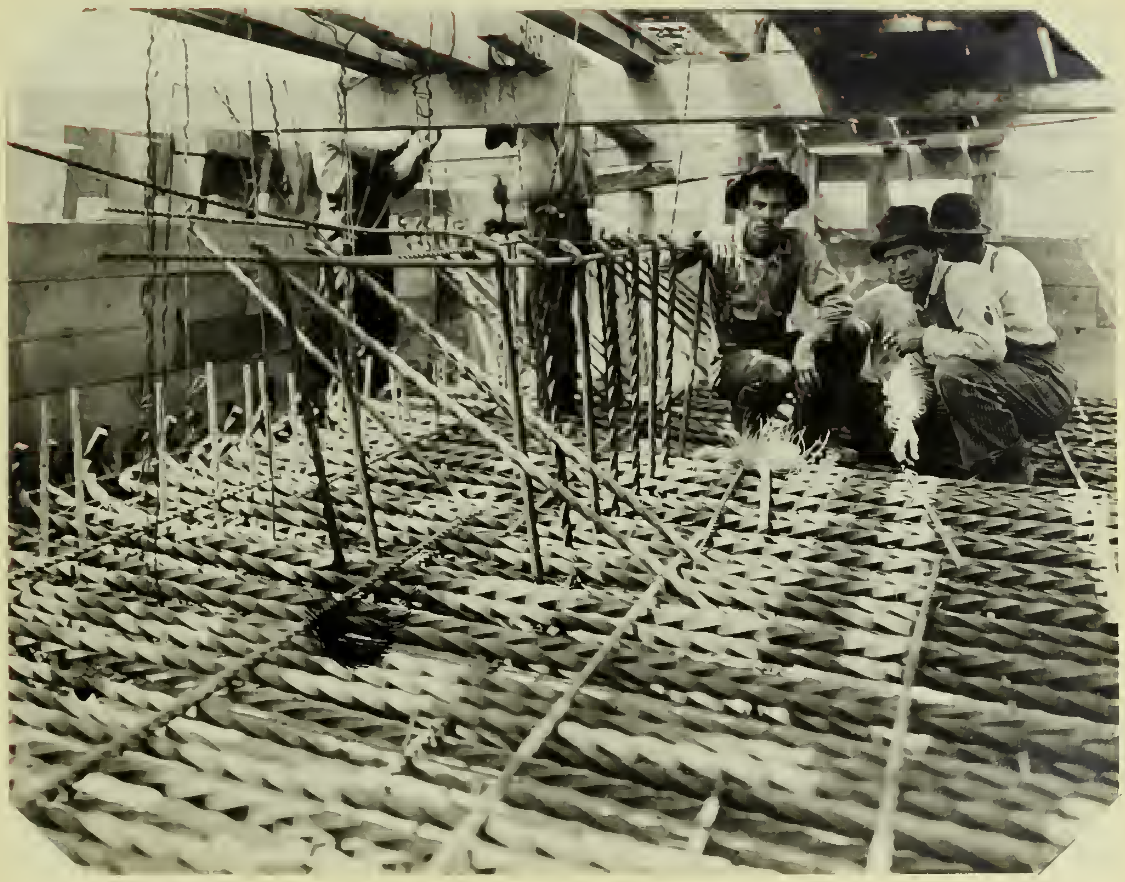
The concrete gang was organized about like the one that did the foundation work, excepting that six extra men were used, two on the hoist, two in the pits facing, and two on top handling the cars. This gang of men placed concrete at a labor cost of about $1.15 per cubic yard.

The abutments and adjoining wing walls were poured in continuous layers without the use of bulk-heads. Along the face walls of the abutments and wing walls were nailed 4- by 4-inch timbers at the elevation to which it was thought that the concrete could be poured in a day's run. The concrete was poured up to a little above the lower face of these timbers. When the concreting was resumed the following day, these timbers were knocked out and the exposed surface was cleaned and the concreting continued. This method gave good joints and caused but little added expense.

BENDING THE REINFORCING RODS.

While the concreters were pouring the abutments and wing walls, a second gang was preparing the reinforcing for the cover. The main reinforcing consisted of one-inch, square-twisted steel rods, twenty-seven feet long, hooked at the ends. The bends had to be mane cold, and on the site of the culvert. This was done in the following manner. A draw-bar head and knuckle was taken out of an abandoned freight car and securely staked down on a level stretch of ground. By the removal of the knuckle and pin a horizontal hole about the size of a twisted bar was afforded. A bar was inserted into the hole to a depth of about four inches, and then five men proceeded with the bending. Four of them walked around with the

PLATE 8.



View showing the reinforcement about one half complete. The hooks on the ends of the main rods are clearly shown, also the vertical and diagonal stirrups. Only part of the supporting wires are in place at this time.

PLATE 9.

View of the cover just before concreting showing, the reinforcement in place, the track overhead and the boxed in supports of the deck. The wires shown are the supports for the main reinforcing as no blocks were used.

bar until the proper bend was made, while the fifth man stayed at the bend and sledged the bar at the same time that the other men did the bending. This method was cheap, quick, and effective. The smaller rods were bent in the same way, but two men usually were sufficient to do the work.

PLACING THE REINFORCEMENT.

By the time that the abutments were complete to the level of the cover, the reinforcement was ready to be placed. The concreting was shut down for a day, and the reinforcement was put in. The main one-inch square-twisted steel rods were placed first, and held to their proper position above the floor by hanging them from the track above by means of wires. These wires could be tightened so as to raise the rods to any elevation desired, and no blocking was required.

The vertical and diagonal stirrups were next placed and wired securely to the main reinforcing as well as to each other and the upper rods. In this way all the reinforcing was rigidly placed so as not to slow up the concreting when the pouring of the cover was started. Everything was then in readiness to get an early start the next morning so as to complete the slab before dark.

POURING THE COVER.

The first few cars brought up water to flush the floor and to help make a good face. The next few batches were composed of sand and cement alone to make a smooth surface on the under side of the cover. These batches made a layer on the floor about

1 1/2 inches thick. Then the regular 1:2:4 mix was resumed, but the concrete was made extra wet until the lower reinforcing rods were covered. Men with specially made spades saw to it that the concrete was kept well spaded around the rods. As the concrete rose on the floor, the posts of the bents settled, but by driving in the wedges at the bottom of the posts, they were brought back to the correct position. The greatest final settlement was two and one half inches, which made an error of about one half an inch in the elevation of the under side of the cover. When the cover was almost complete the mix was changed so as to give the spaders a better chance to make a smooth incline on top of the cover. This was done by changing the mix to a 1:5. The cover was then flushed, floated and troweled to make a good surface for the water-proofing that was to be applied later. The parapet walls were filled as soon as the cover had set enough to prevent the concrete from sliding out at the bottom of the walls. The parapet walls were then flushed, floated, and troweled. This operation completed the concreting, and the gang was transferred to another job.

TEARING DOWN THE FORMS.

Three days later all the forms were taken down except the bents that supported the cover. These bents were left in place for two more weeks. The boxes that had been built around the posts of the overhead track and left in the cover were knocked out and the holes filled with concrete. The wire which had held the walls together were cut off below the surface of the concrete, and the indentations filled with grout. The sheet piling was pulled by four men with a lever arrangement. By the time the concrete had

PLATE 10.

PLATE 11.

Views of the completed culvert after the forms had been removed and the water proofing applied.

completely set, the water-proofers were ready to do their work. All the building material had been carted away, and the premises then presented a pleasing appearance. The culvert was a white monolithic structure standing out clearly against the black earth close at hand.

THE WATER-PROOFING.

The water-proofers then proceeded with their work. The first operation was to clean thoroughly the surface of the culvert with hot acid and then thoroughly rinse it with a solution of strong lime water. The first coat of water-proofing consisted of an application of a thin water-proofing primer. This primer consisted mainly of a thin asphaltic oil mixed with some animal oil, which was applied hot and allowed to harden. Then a thin coat of asphalt was applied and allowed to harden thoroughly. These two coats formed a layer about three-fourths of an inch thick. A final coat of asphalt and gravel was applied and well masticated. With these three coats of water-proofing, combined with the slight slope of the upper surface of the cover, it is safe to say that the cover will remain dry in spite of the large quantities of water that will perculate through the overlying embankment.

The culvert was then ready for the drag-line scrapers to complete the embankment that had been delayed several weeks. Earth was thrown over the culvert to a depth of about eighteen feet, and finally after the embankment had finished settling, the rock ballast was placed. As the culvert was to be used for highway purposes and not drainage, it was unnecessary to pave the floor. So a macadam road was constructed of crush limestone by

tamping and rolling.

The culvert was then ready for traffic both under and over. The total work had been completed in twenty-two working days. Much old lumber and material had been used that otherwise would have been a loss to the firm. Men had been employed who could not have been used on other jobs. Traffic up and down the right-of-way had not been interrupted. Above all a culvert had been constructed that, judged from all engineering experience, would stand the test of time and all the elements and would remain an everlasting monument to modern concrete construction.

PLATE 12.

A small eight foot culvert completed at the same time as the large culvert, showing the water proofing after application.

UNIVERSITY OF ILLINOIS-URBANA
3 0112 086829345